The Post-networked City

Reflecting on Heterogeneous Service Delivery in African Cities

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PHOTOS

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INTRODUCTION

Beyond the Networked City (BNC) is a research project which focuses on the question of infrastructure networks and service delivery in African cities. The project, with detailed cases and rich partnerships in Freetown (Sierra Leone) and Kampala (Uganda), has sought to understand both the empirical and conceptual implications of the rise in infrastructure decentralization and off-grid technologies. This report is specifically focused on the question of off-grid technologies and decentralized models of delivery. It draws both from the cases undertaken as part of this project, and from several additional projects underway at the African Centre for Cities which attend to similar questions, and which have benefited from mutual engagement.

In terms of structure:

- First, this paper provides a conceptual framework, based on insights gained from the project. Against a backdrop of very imprecise theorization, this section aims to develop a more advanced discourse around concepts that are often discussed in African infrastructure spaces, such as "off-grid", "decentralized", and others.
- Second, the paper unpacks the primary case study that was explored for this research – Freetown. Here, we highlight the complexity around on- and off-grid service delivery, focusing on energy.
- Third, the paper looks at examples across Africa of the recognition of networks. We show that considerable innovation is aimed at keeping people on networks, albeit in often unconventional ways.
- Finally, thinking across the various cases and frameworks, we turn to the challenges and risks of decentralized and off-grid provision. In closing, we reflect on the way forward.

The methods underpinning this work include a combination of desktop literature review, fieldwork undertaken in several cities (including site visits and interviews), a review of grey material, and expert interviews with scholars and practitioners. The content has been workshopped with the BNC to ensure coherence and to structure the insights.

SPLINTERED INFRASTRUCTURES AND FRAGMENTED URBAN FUTURES

Over the past 20 years, there has been a landslide of social science and humanities work on infrastructure. Supplementing the more common contributions from economics, engineering, and planning, these two decades have seen essential interventions from various disciplines, including geography, anthropology, and politics. Under the ecumenical umbrella of 'Urban Studies', a so-called "infrastructural turn" has been established which draws together these socio-technical and techno-political framings (Coutard & Rutherford, 2015). These pieces have worked to expand the very meaning of infrastructure – infusing technical systems with social and political theorization.

The infrastructure turn within urban studies builds on the 'splintering urbanism' hypothesis developed and popularized by Graham and Marvin in the late 1990s and early 2000s (see 2002). This literature, and indeed the contribution of Graham and Marvin that inspired it, charted the various ways in which privatization, financialization, and neoliberalism fractured urban material systems, driven by entrepreneurial urban governance models (Wiig et al, 2022). While this work focused initially on English-speaking cities in the Global North (and only anecdotally on cities of the Global South), the splintering urbanism arguments have undeniably gained traction in the context of urban Africa. The rapid development of fancy (and sometimes fantasy) gated housing estates and mega-malls (Watson, 2014), often next to minimally serviced informal settlements, are a vivid expression of the extreme spatial inequality evident in many metropolitan areas on the continent. Scholars show how material (and economic) fragmentation has been driven by the privatization of service delivery (a common outcome of 1980s-style structural adjustment in Africa) (Mizes, 2023), and by the financialization of real estate and land markets, particularly in the urban peripheries (Murray, 2015; Herbert & Murray, 2015).

In African urban areas, this splintering reflects the continent's history of infrastructural fragmentations. Africa's contemporary infrastructural situation cannot be divorced from colonial planning and urban management (Fox, 2014). Even before structural adjustment processes in the 1980s and 1990s, infrastructures in many African cities were deliberately "splintered", to divide populations across racial lines, control urban population growth, and realize the extractive goals of imperialism (Von Schnitzler, 2008). Postcolonial and developmental efforts aimed at improving these systems have often increased their fragmentation and fallen short of their promise of integration (Bass, 2011). There are many reasons for this, including limited resources, slow bureaucratic processes (also a colonial legacy), and a plethora of issues related to land ownership and access (a critical part of effective service delivery) (Briceño-Garmendia et al, 2009; Jaglin, 2008).

Despite the generally limited role which Southern (and particularly African) cities have played in wider theoretical debates, the infrastructure turn in urban studies has been shaped considerably by cities on the so-called periphery (Baptisa & Cirolia, 2022). African cities have provided fertile ground for key conceptual disjunctures to be explored. They have provided new and creative thinking on themes such as infrastructural leapfrogging, repair, failure, and transitions. This is undeniably one of the few areas where African cities have not only nuanced global theory-making, but produced theoretical work that has had applicability in the Global North.

One of the more productive debates which has emerged from Southern scholarship relates to the "networked infrastructure ideal" and the "post-networked city". The networked infrastructure ideal refers to the belief, often implicit in development discourse and scholarship, that cities can and should pursue large-scale, homogenous, and centrally controlled urban networks to deliver services such as water or energy (Jaglin, 2014). This ideal rests on the belief that these networks provide optimal infrastructural conditions, allowing for large up-front costs to be amortized over long periods, cross-subsidization between different user groups (rich/poor, industrial/residential, etc.), accountability between providers and end-users, and for essential trade-offs to be made between developmental objectives (such as between access and economic growth). Scholars who study post-networked infrastructure argue that African cities challenge this ideal.

Over the past 10 years, scholars interested in African cities have pushed us to question if networked infrastructure is not only impossible to achieve, but in fact an undesirable aim. Many have questioned the basis for the networked infrastructure ideal, suggesting that such aspirations are informed by modernist visions, often refracting colonial ideas of progress and order (Baptista, 2019; Jambadu et.al, 2023; Lawhon et al., 2018; Guma, 2020). Scholars and development actors ask the following questions: Is this ideal both possible and beneficial in cities with weak states and limited infrastructure networks? Does such an idea militate against innovative technological and institutional alternatives? And finally, if cities are in transition, what sorts of ideals and imaginaries of post-networkedness might this enable or presuppose?

DECENTRALIZED TECHNOLOGIES AND HETEROGENEOUS DELIVERY SYSTEMS

Against this backdrop, post-networked solutions are often presented as the only way to address urgent needs and pursue alternative development pathways. Scholars of African cities, in particular, show how self-organized, informal, popular, and private provision dominate city systems, filling gaps in large technical and networked systems. These gaps, authors show, may exist where centralized networks have fallen into disrepair or, as is commonly the case, never existed in the first place (Nilsson, 2006; Jaglin, 2008; McFarlane & Rutherford, 2008; Akallah & Hård, 2020). They are necessary for the everyday functioning of urban systems, providing livelihoods and service options to the majority.

However, not all the alternatives to large utility networks have taken the form of informal and makeshift solutions. Energy is a good example of this. Partly because of the absolute necessity of energy as an input into many activities fundamental to urban life, there are a wide range of infrastructural processes and pathways – across scale and level of formality – creating what Jaglin refers to as "electrical hybridity" (Jaglin, 2016; Rateau & Jaglin, 2022). Some operate where gridded infrastructure is not in place at all, providing options such as lanterns or firewood to households in informal settlements (Smith, 2023), or mini-grids to communities that are not serviced by existing utility networks (Jaglin, 2019). Other pathways overlay on top of existing grids, supporting in the context of disruption, failure, and intermittency, such as UPS devices, inverters, or home-based solar systems (see Jagin's [2023] work on rooftop solar in South Africa). Still others are formatted specifically to coexist in parallel with the grid to meet different needs, such as LPG networks for cooking or battery-charging stations for e-vehicles. In addition to nuancing our understanding of how hybridity manifests, and skilfully emancipating the concept from its assumed correlation with poverty or informality, this scholarship is attentive both to the value of diverse material practices and social connections (see, for example, Silver's analysis of the social networks formed through such arrangements).

Within the current development debates, the decentralized service-delivery paradigm for African cities is often seen as a panacea by donors, planners, and academics. The use of 'off-grid' methods is often presented as the only "modern" (Kroll et al., 2019) option in contexts where networked service delivery is limited or does not exist at all. Beyond the development scholarship, which celebrates all these innovations, critical scholars also hold a unique sort of optimism in this scholarship, one which positions developing (and particularly African) cities not as passive sites of neoliberal destruction (as splintering urbanisms might suggest), but as places of imaginative experiments, perpetual becoming, radical revision, and post-networkedness possibilities (Simone, 2008; Odendaal, 2021). This discourse has shaped all manner of investment in decentralized technologies – from tech start-ups that focus on home solar systems, to aid organizations that supply water kiosks, to Development Finance Institutions which fund waste-picking centres. While it is undeniable that existing networks are failing many communities, the substance and specificity of the off-grid reality needs to be interrogated (Misra & Kingdom 2019). The social, ecological, political, and cultural dimensions are vital to consider.

In addition to the celebration of off-grid services, we have seen a celebration of the role of city governments in addressing questions related to African infrastructure futures. There has been a surge of excitement across Africa related to the joint processes of both material distribution and governance decentralization. It is widely assumed that these processes will together move decision-making closer to communities and ensure that service-delivery approaches reflect the unique needs of cities and their dwellers. This celebration equally attends to the widespread assumptions that centralized networks have failed to deliver on the promises of networked monopolies and require much stronger levels of accountability and reciprocity, which are believed to exist at urban and suburban scales.

In this research, we sought to create a conceptual framework that disaggregates service-delivery and infrastructural configurations. We found that, by identifying vectors of infrastructural arrangements, we were able to develop a richer vocabulary. Our research found that, within the context of post-networked and decentralized services, there are a wide range of typologies and structures. Across sector and city, decentralization can take many forms, encompassing various levels of regulation and scalar assemblages.

TABLE 1: VECTORS OF INFRASTRUCTURAL DIVERSITY

VECTOR	DECENTRALIZATION
Social and institutional organization	We see a wide range of social organization approaches among infrastructure typologies. These range from highly individual to much more collective. These collective approaches may also have institutional overlays, such as community organizations – institutionalized to various degrees – established to manage service systems. Fully institutionalized systems are generally managed by agencies of the state.
Scale and connectivity	In terms of decentralization, scale refers to the size of the coordinated components of the infrastructure. Large-scale systems reflect coordination and connections to city-scale, national or event supra-national networks. Smaller-scale technologies operate as isolated systems at the sub-urban or even household scale (such as pit latrines). These may be completely disconnected, or connected to small networks.
Economic and fiscal	Decentralized systems often reflect a blurry combination between developmental intention/ subsidization and profit-making/ growth. Some decentralized systems are primarily for the function of economic growth (for example, hybrid mining projects), whereas others are for poverty-reduction (such as community mini-grids) and require high levels of subsidization of the capital costs or tariffs.
Consumer group	Linked to the above context of developmental objective, there are also a range of consumer groups that decentralized services aim to attend to. For example, decentralization may be used to attend to a residential community that is not serviced by the grid, as opposed to an industrial part of a commercial enterprise that is water- or energy-intensive.
Regulation	While the state often regulates the centralized provision which it manages, those provisions that are managed by private-sector actors may experience more, or less, regulation. The outcome is that such systems, and therefore its parts, may be more, or less, informal. Alternative bodies might also produce industry standards and parallel regulatory systems (for example, minibus-taxi regulatory bodies). The extent to which regulation exists and is implemented varies.
Type of service provider	Decentralized infrastructure can be managed by public, parastatal, or private entities, or a combination thereof. Different parts of the network or service-delivery configuration may also have different levels of privatization (for example, generation could be public, with distribution being private).
Technological complexity	Decentralized infrastructure can be very low-tech or very high-tech, depending on the context. Higher-tech systems generally have higher up-front capital costs, with lower labour requirements. Lower-tech systems generally require more 'work' to run them (for example, waste collection and picking).

Source: Compiled by author, adapted from Cirolia and Pollio, forthcoming.

DEEP DIVE INTO ELECTRICITY IN FREETOWN

Focusing our attention on Freetown, and referencing the framework above, we explore the ways in which off-grid services have come to fill the gaps in networked provision. We also look at the ways in which partially networked solutions – or reconfiguration of existing networks – present alternative futures for infrastructure in the city. Given the ways in which African local governments have been presented within infrastructure debates, we situate this discussion against the backdrop of Freetown's own governance arrangements, and the city authority's limited capacity to transform the city (despite ample political will to do so).

Freetown, a beautiful port city and the capital city of Sierra Leone, is surrounded by beaches and borders a large and lush nature reserve. The city is surrounded by natural resources, but suffers many of the legacies faced by West Africa's urban areas. Blighted by the painful legacies of colonialism, slavery, and more recently civil war, the county is rebuilding itself with limited resources and a contentious development complex. Rapid inflation, donor dependence and weak infrastructural networks are just some of the catalogue of challenges facing the city and region.

Recently, the city of Freetown, and particularly the Freetown City Council (FCC), has been catapulted into the global urban spotlight by the determination and positioning of its mayor, Yvonne Aki-Sawyerr OBE. As a representative of the opposition party, the mayor has sought to strengthen the city's international positioning by attracting donor investment and international expertise. The vast majority of Freetown's projects are built by donors and NGOs, while the city's own resources are used to cover the basic operational costs of the administration. The Transform Freetown Strategy, driven by the mayor's Delivery Unit and supported by a cadre of intentional fellows, is the flagship of the administration, used to channel donor investment into selected priority projects.

The FCC, and particularly the Mayoral Delivery Unit, has been at the forefront of many urban climate fora, showcasing the city's impressive tree-planting programmes, which have been positioned as key to addressing climate-related hazards and risks. The city has managed to activate all manner of donor direct investment in community facilities, natural resource preservation, heritage sites and the like. The FCC is currently seeking to attract finance to develop a cable car to address mobility challenges, and is undertaking the scoping study with the support of German development agency GIZ.

Despite these impressive efforts, the FCC holds few of the functions needed to operationalize plans for many of the critical urban issues. It also has limited resources, with national transfers constantly delayed and donor expectations constantly shifting. Having been unable to secure powers over land administration and planning, development choices are largely dictated by the national ministries (despite reforms which have sought to decentralize these functions). The FCC has little to no control over many of the most pressing urban services, such as water and energy. These major urban functions have remained at the national scale. There are various reasons for this, as the resource value chains needed to support service delivery require expansive coordination across territorial boundaries, both local and international. However, it has meant that the city has little say in the investment priorities – or long-term vision – for these critical networks.

Freetown, like many cities in Africa, has large material systems which support the delivery of electricity. Unlike services such as energy for cooking, where distributed systems and long value chains have been encouraged and are dominated by the private sector, most of the Freetown's areas have some level of coverage for electricity, provided by national utility companies. The Electricity Distribution and Supply Authority (EDSA) is responsible for electricity provision in Freetown. Most electricity is provided by Karpowership, a Turkish company using a ship stationed in the harbour, visible from the newly developed municipal offices. The ship provides over 90% of Freetown's electricity supply. However, the tariff charged by EDSA to consumers – coupled with losses associated with theft and line degradation – fail to adequately cover the cost of purchasing this power. While many are concerned that the country is paying such a high price for energy (and running up debts with the company), others are relieved. As one interviewee noted: "We would not be sitting here now having this conversation if it were not for that ship." Notwithstanding this now common method for ensuring generation capacity, there remain considerable challenges with regard to ensuring reliable supply of electricity to the city. Regular blackouts, lasting hours or even days, are common. And parts of the city are yet to be connected to the network at all.

There are numerous and varied explanations for the infrastructural failures the city faces. Many cite the fact that Freetown was planned for a fraction of the population, with urban growth putting considerable strain on already congested networks. Limited access to finance, coupled with near-complete reliance on donors for capital investments into infrastructure networks, are some of the reasons behind how this network can exist – and fail – at the same time. Moreover, the challenge cannot be reduced just to one of generation/production: while it is important to ensure there is ample supply of electricity, the actual networks needed to distribute it have also been under-maintained.

In the absence of a fully functional network, the vast majority of households and businesses have come up with their own solutions. These solutions are not only used in areas where the grid does not reach, but also in areas where the grid is present but the flow of energy and water is inconsistent. These solutions are generally small-scale and partial, used to fill the gaps in the network. What do these household solutions look like? For energy, these technologies include lanterns and generators. Firewood and candles are used for heating, cooking and basic lighting. With limited capacity to invest, the choice is almost always the option with lower upfront costs – even if this means higher operating costs. For example, diesel generators rather than solar-powered ones. Companies that want to fit homes with solar products, such as Easy Solar, need to develop smart models for 'pay as you go'; models that allow for consumers to spread the costs over the lifespan of the assets (which are still generally short – just a few years).

These solutions are used by the poor and the rich alike: for example, in the case study of energy access in Portee-Rokupa – a low-income and partially informal settlement – we see a range of service-delivery solutions. Based on interviews and surveys conducted in 2022, the Beyond the Networked City project found that – despite considerable levels of grid connectivity – most households (97%) relied on back-up means for lighting. The most popular alternatives were mobile-phone torches (71%) and battery-powered torches (69%). Households believed that the quality and standards of these low-end technologies was poor, with 79% replying that privately purchased equipment regularly broke down. Our open-ended data suggests that the culture of change, repair and maintenance is common with household lighting products. Moreover, energy for cooking is completely non-networked, outside of any national utility and mainly provided by the private sector and donor-funded initiatives. Despite this, even if a centralized network (gas or electricity) were to be fully functioning in these spaces, it would only be one option amid a plethora of cooking technologies and fuels. The use of the term 'off-grid' in this context is not useful. Charcoal was ubiquitous in Portee-Rokupa (unsurprisingly), with 96% of respondents stating they used it as their primary cooking fuel. When considering the alternatives, 36% use firewood and 6% use LPG. Respondents stated that fuel is easily accessible (94%), available (90%), has a large number of suppliers (85%), is affordable (67%), and the quality meets their expectations (64%). When disruptions are experienced, respondents turned to alternative cooking fuels (79%) and suppliers (94%), with a small majority preparing meals for the entire day at one time (60%). Charcoal is also preferred in rented accommodations, as landlords consider it safer than wood or LPG. Nearly all households use a coal pot as their cookstove technology (97%), with 56% of respondents stating that it breaks down regularly and there is a need to purchase a new one.

Overall, these technologies – generally implemented at the household scale, allow people to manage the perpetual strain caused by service-delivery disruptions. The choice of technology, of course, differs for those who have grid access and require only supplements, versus those for whom no networked access is available. Similarly, the choice differs for people across different income levels and business typologies. Wealthier businesses and establishments may manage, slightly more gracefully, to ensure that there are backups for the backup, and that the transition between EDSA supply and generator only takes a few moments. Some, like the World Bank offices in Freetown, may be designed from the start to be 'off-grid', to avoid the need to move between localized and networked systems. Despite these important differences in what is affordable and preferable to different communities and people, the strain of these partial and under-resourced networks is ubiquitous,

with the only 'winners' being those who have created livelihoods from providing solutions – whether through providing short-term supplements or mini-grids for communities. There are many implications of this approach. For one, it shifts the risks – often accounted for in the redundancies built into large technical systems – onto households. This is costly for both the rich and the poor, consuming resources that could be used in other, more productive, ways. At the same time, there may be unexpected life cycle costs of these technologies, such as e-waste.

In some cases, there are intermediate solutions between the city-wide network and the household. IIn some areas, mini- and micro-grids for energy have been established to provide services where the network does not reach or does not provide the quality of supply. Institutional actors have developed microgrids to enable a more reliable supply. For example, a government-run health centre in Freetown has developed a 300 kWp solar minigrid, to replace the diesel generators previously installed, through the Sustainable Energy for All programme. Similarly, the banking sector such Standard Chartered Bank in the centre of the business district has not only built a 132 kWp solar minigrid to power itself but is also increasingly providing finance loans for minigrid initiatives (such as that in Angola). These can provide a resilient, dependable, renewable power supply , which augments the supply from the grid and provide a critical backup for equipment.

However, apart from a few examples (of mainly elite institutions being able to fund this type of infrastructure), formal mini-grids are not common in Freetown. Permits for these sorts of large and long-term investments have been granted outside of the city, where EDSA and the regulator (the Electricity and Water Regulatory Commission) believe the network will take a long time to reach. There are a plethora of international donor funded initiatives (E.g. UK FCDO) that have large rural electrification programmes through the installation and use of minigrids. These installations are mainly in areas where there is no grid infrastructure, yet the long term implications for minigrids such as ownership, maintenance and tariff structures are potential challenges for when grid infrastructure is eventually rolled out in these areas (such as parts of the CLSG line). Within the city, more common forms of mini-grids are developed by community members, running large generators and allowing for groups of surrounding households to connect, charging and managing the fees based on a variety of factors, including the cost of diesel and the labour involved in managing the small system. These intermediate solutions, existing between the centralized grid and the individual home-based technology, are not common. They exist more commonly in informal areas, peri-urban communities, or (even more rarely) in new estates, where the developer has built in self-sufficiency.

Questions remain regarding how these mid-range solutions will come to (inter)operate with the grid. As the leader of an NGO that develops water solutions noted: "It is unclear who is meant to regulate us, and to whom we must pay for the right to operate in Guma Valley territories." There appear to be clear guidelines for how to establish electricity mini-grids; however, the question of what will happen if and when the grid reaches these areas remains unsolved. While EDSA says it will simply 'take over' these systems and lower the cost of energy to them, mini-grid providers reminded us that they have investors who have supplied finance to these projects, based on 20-year revenue projections and, as such, would need to be generously compensated.

This brings us to a final and pressing question: what are the various imaginaries for networked access – and its future development – that exist among stakeholders in Freetown? When it comes to informal (low-income) settlements across the city, there is not so much a future imaginary for the network, rather than an inclusionary approach which considers the needs and voices of these communities in broader, policy, governance and infrastructure discussions (at both the local and national level). Indeed, our interactions with stakeholders working directly in and with informal settlements across the city noted the need for change in Freetown. "We learn from Rwanda; they wanted to create change for the city, [but] they excluded people from the informal settlements. [If] We are part of it – then it can work." Our interactions very much reasserted the narrative that informal settlements across the city have some form of access to the centralized network and, if unavailable, communities themselves will most likely use other means (decentralized) to access the services they require. Overall, the utilities responsible seem unfazed by the diverse and overlapping strategies through which households and firms secure access to services.

In the case of informal settlements, where the cost of meters are high, multiple households often connect to one meter box (load, capacity and configurations of meter box unknown). In the eyes of the utility, this is not an issue. As put by a utility employee "As long as people are accessing electricity through an EDSA cashpower box, it is not a problem." With severe constraints on supply, and a tariff which does not reflect their own cost to secure these resources, having people opt out of the system does not seem to raise any alarm. As one official told us: "We know we cannot supply, so it's OK that people make other plans." More concerning for officials and technocrats are those who use services they do not pay for. As we were told: "Both the rich and the poor refuse to pay. This is very bad for us. Particularly when big hotels or government offices refuse to pay."

Notwithstanding the severe limitations, officials are committed to universal access, citing all manner of strategies and documents, from global goals to local master plans. These plans are materializing in somewhat predictable ways. For energy, new investments in a regional energy corridor will potentially come to replace the need for Karpowership, securing energy access for the city. The new investment, called CLSG, links the four countries highlighted in the acronym: Côte d'Ivoire, Liberia, Sierra Leone and Guinea. Specifically to Sierra Leone, it involves the construction of a transmission line of approximately 1,500km across eight districts leveraging on the hydropower potential in three out of five planned substations. As one CLSG representative told us " [it is] a conscious effort to see how best we can harness [our] hydro potential". At the time of writing, the CLSG transmission line into Freetown was experiencing varying success with notable technical disruptions in December 2023 that plunged the city into darkness.

Notably, the research found that off-grid technologies are not the only way in which non-utility scale, post-networked service delivery is achieved. In the following section, we look at some of the examples of decentralization that form part of – or interface with – the utility network.

EXAMPLES OF DECENTRALIZED 'NETWORKED' TECHNOLOGY FROM ACROSS AFRICA

In this section, we explore the ways in which decentralized technology forms part of utility networks, both in the case of cities, and based on the authors' wider research. **These examples, we argue, shore up the complex relationship between centralization and decentralization, and on- and off-grid services. Beyond the discussion above, there are insights which can be drawn from work across Africa.**

High-tech decentralized sanitation driven by the city authority:
In Addis Ababa, Ethiopia's capital, the city government has encouraged the use of decentralized technologies for the middle classes. Less than 10% of the city is covered by networked sanitation. Instead, vacuum trucks collect sewage from households. In sub-urban developments on the outskirts, where middle-class households have purchased subsidized houses, the water and sanitation company has experimented with high-tech decentralized solutions – such as membrane bioreactors (MBRs) and similar decentralized options. Originally conceived for industrial usage, MBRs are now used for medium-scale building complexes which don't have access to networked wastewater systems. The city's water and sewerage company has been involved in deployment and management of these systems. In the case of Addis's condominiums, modalities which are not imagined as part of the centralized and state-provided network are in fact state-provided, and even subsidized. They are smaller self-contained mini-grids, connecting a grouping of houses to an isolated system. These are solutions aimed at the middle class, not the very poor; solutions necessary for unlocking the (highly political) housing projects which have forged forward despite the lack of infrastructural connectivity. The case suggests that heterogeneity can be seen in high-tech, middle-income, small-scale solutions which are driven by the state but exist outside of its regular functionalities.

E-mobility: Boda boda (motorcycle taxis) are an interesting example of a mobility system that exists in place of networked public transport. With minimal formal regulation, boda boda fill the gaps in the last-mile needs of Nairobi's residents across class and urban geographies. Motorcycles are, however, fossil fuel-dependent, and their life cycle is short. Addressing this, many 'start-ups' are experimenting with retrofitting and electrifying boda bodas – giving them batteries and building charging stations. Kenya's current power generation is higher than current usage, and mostly coming from green sources (more than 80% of Kenya's electricity comes from renewables). By increasing effective demand, these companies will contribute to the state fiscus by reducing its dependence on fuel imports, which are highly subsidized and therefore a constant budgetary headache for an indebted nation like Kenya. This story of 'green transition' shows how networked (green electricity) and non-networked systems (boda bodas) can exist in a symbiotic relationship.

Delegated water management driven by the county utility: In Kisumu, a smaller city on the Kenyan coast of Lake Victoria, the sub-nationally owned water and sewerage company (KIWASCO) has partnered with community enterprises to extend water services to informal and low-income communities. Rather than clamping down on illegal connections, they developed a 'Delegated Management Model' to allow for small-scale providers to extend the infrastructure system and manage access, non-revenue water, and tariff collection at the local level. Without overly romanticizing these efforts (there is ample scope here for conventional [anti-]neo-liberal critique, as well as pragmatic reflection), the incredible scale of access enabled through this delivery model is notable, and this model has been used elsewhere in the world. Utilities, especially those sitting under state departments, have had to find innovative ways to make services accessible in contexts where existing models of delivery are impossible. Kisumu's example shows how centralized systems can be extended through formal – yet distributed – systems of management. It shows how heterogeneity can be baked into state-led projects, if utility companies are able and willing to work with the messy realities posed by micro-enterprises and informal-settlement dynamics.

IDENTIFIED CHALLENGES OF DECENTRALIZED AND OFF-GRID TECHNOLOGIES

Our research has identified a range of issues related to decentralized, and particularly off-grid, service-delivery methods.

The costs for both the poor and the utilities is a key issue. One of the major risks and issues with regard to off-grid services is that such services are often privatized, and thus are used by those who can afford it. Off-grid services often come at a premium, thereby excluding the poor, who would often be the key beneficiaries of such a system. In the case of low-income families, the ability to afford even the lowest-cost technologies can be an issue. This often results in people using very low-quality technologies or ecologically hazardous options (addressed in the following sections). In contrast, for middle- and higher-income households, the choice to 'leave the grid' by sourcing off-grid technologies can weaken the capacity of the utility to raise revenue for service provision and infrastructure delivery. Having large commercial consumers leave the grid is even more challenging, as these consumers generally pay the highest tariffs. At the same time, having higher-income customers leave the grid may create long-term impacts, as it is difficult to get these customers back, even when the grid is eventually invested in and upgraded. Fiscal tension is placed on centralized utilities when wealthier customers and commercial users exit the shared system, leaving only the poor on the (often under-serviced) network (Jaglin, 2023).

Regulation of decentralized technologies has also raised concern. In the cities which formed part of this study, interviewees articulated issues with the lack of regulation of decentralized technologies. For example, imported products have often not been tested. There is some regulation on things like mini-grids, but generally this regulation is developed in favour of developers and financers, and is often inappropriate, with a lack of connectedness to broader social, technical or financial factors (Shrestha et al., 2019). This is echoed in the International Energy Agency's 2022 report, which states: "The solar PV reuse sector is still mostly unregulated." Research also suggests that, in many countries, the import of solar products for home use is largely unregulated in terms of quality – with direct implications for lifespan.

Despite claims that decentralized and off-grid technologies are greener or more circular, off-grid technologies often have hidden ecological impacts that require regulation.

With solar products, a life cycle analysis of the decentralized technologies, like solar home-system kits, suggests that – both in terms of production and disposal. For energy technologies, there is also an emerging geopolitics of e-waste and end-of-life disposal. This was particularly flagged by officials in Kampala. Most cities in Africa have no plans in place for managing e-waste. We are already seeing solar panel graveyards in developed countries—in cities where considerable portions of the urban fabric are unregulated, there is a huge risk that cities (particularly peri-urban areas or informal settlements) become dumping grounds for toxic and high-risk materials.

Centralized value chains present issues for job creation and economic development. The value chain for off-grid systems is typically complex. Most systems are imported with sporadic manufacturing or production capacity in-country, ad hoc assemblage practices, and no provision for product end-of-life. In addition, the continuous need for reskilling and upskilling the current workforce (Li, 2022), as well as a male-dominated engineering culture that often dismisses gender (Pailman & de Groot, 2022) in the broader sense raises questions around sustainable off-grid value chains.

Value chains for higher-tech systems seem to be largely outside of Africa (e.g. solar products). For example, China has been a major player in decentralized energy technology. China has focused strategically on providing state support to Chinese manufacturers by providing cheap debt at state bond rates in exchange for ownership requirements. This investment has yielded results: approximately 40% of the global supply of the high-grade polysilicon required for solar panels is sourced from China's Xinjiang region. China also controls the lithium-ion (Li-ion) battery manufacturing sector, a key battery of choice for many mini-grid projects. Although lead-acid batteries are being deployed in some mini-grid projects (for example, in Nigeria), Li-ion batteries are still the choice for many grid projects in Africa due to efficiency, longevity, and discharge capacities. Notably, movement towards smart solutions is likely to experience even weaker localization of value chains and opportunities for value extraction, owing to the high-tech nature of these. Global manufacturing chains often produce complex universal 'one size fits all' product families which, at lower powers, can be considered consumables and, at higher powers, require specialist repair facilities. Many companies often develop products for African markets, especially within the off-grid lighting sector, utilizing centralized manufacturing located outside Africa, and then import their technology into the market (examples include d.light, Easy Solar and Bboxx).

This model enables low-cost products suitable for the market, but with minimal support for local design and manufacturing capacity, or consideration of end-of-life for the product. Interactions in Freetown noted that Easy Solar products (panels and lights), for example, only have a two-year lifespan and, as yet, no corporate end-of-life strategy. It also blocks small, local manufacturing companies from entering the market, especially those from African economies. There are some companies, such as BURN Manufacturing, which started in a design studio in the US and have now developed manufacturing capacity in Kenya, building charcoal cookstoves locally for both the national and international markets. However, these examples are few and far between (and often difficult to determine via company websites or reports) , and are often limited to low-end technologies such as cookstoves.

There is further pushback against the centralized supply and manufacturing paradigm; resistance which can be seen in the use of open-source design, local manufacturing capacity and internet-based knowledge-sharing (broadly understood as cosmolocalism) (Kostakis et al., 2023a; Kostakis et al., 2023b; Giotitsas et al. 2022; Kostakis et al., 2021; Butchers et al., 2021; Butchers et al., 2020; Kostakis et al., 2018; Kostakis et al., 2015). This method of open-source design and local manufacture has been widely used in Nepal for small-scale micro-hydropower turbines since the mid-1970s, with the support of development organizations (Paish, 2022). The success of this can be seen through over 3 300 locally manufactured turbines operating in the country, providing off-grid power to communities, and building a thriving local industry that can develop the technology (Butchers et al., 2020). Another example of this is the proliferation of the Piggott wind turbine, using a 'recipe book'. These designs, and the interactions between manufacturers, have been supported through donor-funded organizations such as the Hydro Empowerment Network (HPNET) and Wind Empowerment, providing opportunities for industry to network and learn from each other. However, there are few of these examples, where products are localized and built or even assembled in the local country. The decentralized service-provision sector presents a prime opportunity for local manufacturing. Products are often physically smaller, requiring less investment in large, capital-intensive manufacturing equipment (especially as products can be ordered in smaller quantities). Services are well understood by the companies, so modifications to the global, commons-based designs can be culturally and socially appropriated. Equipment can also be supplied directly to consumers or through local agents, providing rapid feedback on design suitability.

Redundancy and its costs for end users is a major issue. Across disciplines, redundancy means different things. It can, for example, refer to a technology or role which has become obsolete (e.g. improved cookstoves). In the context of engineering – a core discipline underpinning urban infrastructure studies – redundancy refers to components designed to backup systems in cases of failure. One of the core value propositions of redundant systems is that these backups are decentralized, so that various pathways and possibilities for functionality and optionality exist. In African cities, service-delivery systems endemically operate only partially. There may be pipes but no water running through them, peripheral areas of the city where networks only partially reach, or porous bureaucracies. Within these partialities, designed redundancy becomes the responsibility of the user, forming part of incremental patchworking at the household and community scale. In effect, hyper-decentralization. In the context of partial networks, households carry the risk of everyday breakdown, and the cost of building redundancy into the system. While this redundancy could be framed as resilience and adaptation in the face of limited alternatives, it is in fact incredibly costly and taxing, not only for the poor but also for the middle class. Clear examples of this used-designed redundancy can be seen in the data from Kampala and Freetown, with consumers using a variety of sources for lighting, cooking, and drinking water. During fieldwork in Freetown, local colleagues explained the importance of using multiple mobile phones on different networks, as signal varied or was unavailable in different areas within the city.

Weakening of urban local governments and utilities is a major issue. There are considerable risks around urban governance that need to be considered in the shift towards decentralized technology and off-grid options. As we saw in the research, decentralized systems are often installed by donor organizations, who are unable to maintain the system in the long term, and so either fail to reap benefits beyond the funding scope, or ultimately fall into disrepair. There are long-term outcomes of under-sourcing utilities rather than reforming them or investing in them. The pseudo-privatization of utility services takes powers away from the state – also in terms of accountability. This results in the reduction of the mandate of local government, weakening its capacity to support local development and guide development pathways.

CONCLUSION

Within the current infrastructure debates, there is significant debate about the future of centralized utility networks, and the associated governance models. While many argue that centralized networks are the only way to deliver affordable services in highly uneven social and material contexts – by ensuring that economies of scale and cross-subsidization can be supported – others argue that this is impossible. Proponents of a shift towards decentralized, distributed and off-grid models of delivery argue that centralized networks have lent themselves to bureaucratization and elite capture and that, practically, alternative service delivery pathways have always existed alongside efforts to network, and will continue to do so as technology progresses.

In the context of Africa, the question "To network or not to network?" is a challenging one. Not only does it raise normative questions (What is good or right?) – it also raises ontological questions about the nature of networks themselves (What makes something a network?) and practical questions related to the contingent and temporal pathways of infrastructure development in African cities.

This piece focuses on off-grid services, making the following arguments :

1. In the context of urban areas, off-grid technologies are often used to supplement grid access rather than replace it. Off-grid technologies form part of a continuum of diverse ways in which service delivery is constituted in African cities, which also include smaller networks (e.g. mini-grids), illegal networking (e.g. tapping electricity or water lines) and grid-linked storage that helps to manage issues of consistency and flow (e.g. batteries, water tanks).
2. Off-grid technologies form part of alternative networks, driven by production and logistics processes. These networks shape access, affordability, maintenance, and the distribution of benefits. Defining and foregrounding these networks allows for a richer engagement with questions of value chains and network-building.

3. In the urban context, off-grid technologies present particular opportunities and challenges. When supporting these sorts of projects, particular care should be taken to address these risks.
4. There are long-term outcomes of under-sourcing utilities rather than reforming them or investing in them. The pseudo-privatization of utility services takes powers away from the state – also in terms of accountability. This results in the reduction of the mandate of local government, weakening its capacity to support local development and guide development pathways.

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